Seasonal Prediction for Ecosystems and Carbon Cycle Using NCEP/CFS and a Dynamic Vegetation Model

Ning Zeng (PI), Eugenia Kalnay (co-PI)
Dept. of Atmospheric and Oceanic Sciences and Earth System Science Interdisciplinary Center, University of Maryland
E-mail: zeng@atmos.umd.edu ; Phone: 301-405-5377; Fax: 301-314-9482

NOAA Collaborator: Arun Kumar
NCEP Climate Prediction Center

Introduction

In recent years, many advances have been made in the science and practice of seasonal climate predictions. For example, seasonal climate predictions have attained operational status and have come to rely increasingly more on dynamical prediction models. Such advances notwithstanding, application of seasonal climate outlooks to applications of societal importance has been slow to materialize. The aim of this proposal is to develop one such application, i.e., *a capability to forecast terrestrial ecosystem productivity and carbon sources and sinks on seasonal-interannual time-scale.* The modeling system is global, but the focus of validation and application will be for North America.

The development of an outlook capability for the ecosystem will rely on several components that have evolved following independent pathways and have reached a state of maturity in their respective domains of interest. The key effort of this proposal will be bringing together these modeling and prediction component systems.

The modeling components of the proposed predictive capability include:

1. A dynamic Vegetation-Global-Atmosphere-Soil (VEGAS) model with full terrestrial carbon cycle
2. Operational climate forecasts at the Climate Prediction Center and dynamical seasonal forecasts based on the Climate Forecast System (CFS) (both at NCEP)

Specific tasks under the proposal will include (and will build upon a prototype carbon cycle prediction already in place):

- Developing a procedure to specify vegetation and soil initial conditions derived from some form of data assimilation system
- Developing procedures to forecast ecosystem and carbon variables using ensemble climate prediction information from CFS
- Validation of prediction system based on hindcast skill by comparing model predictions against a suite of observed variables such as satellite vegetation index, CO_2 flux measurements, and assimilated carbon fluxes
- Comparison of the CFS based skill with other baseline estimates of skill for predicting eco-carbon variables, e.g., prediction based on operational CPC forecasts
- Testing the prediction system in a real-time operational setting, getting feedbacks from a wider community, improving the system.

Deliverable of this project will be a seasonal forecasting system for terrestrial ecosystem productivity and carbon fluxes that later will be transitioned to operations using the Climate Test-Bed (CTB) infrastructure.

Results and Accomplishments

Hindcast experiments

We have conducted a 25-year hindcast experiment to explore the possibility of seasonal-interannual prediction of terrestrial ecosystem and the global carbon cycle. This has been achieved using a prototype forecasting system in which the dynamic vegetation and terrestrial carbon cycle model VEGAS was forced with the 15-member ensemble climate prediction and lead time up to 9 month from the NCEP/CFS climate forecast system. The results show that the predictability is dominated by the ENSO signal for its major infuence on the tropical and subtropical regions, including the Amazon, Indonesia, western US and central Asia. The hindcasted ecosystem variables and carbon flux show significantly slower decrease in skill compared to the climate forcing, partly due to the memories in land and vegetation processes that filter out the higher frequency noise and sustain the signal.

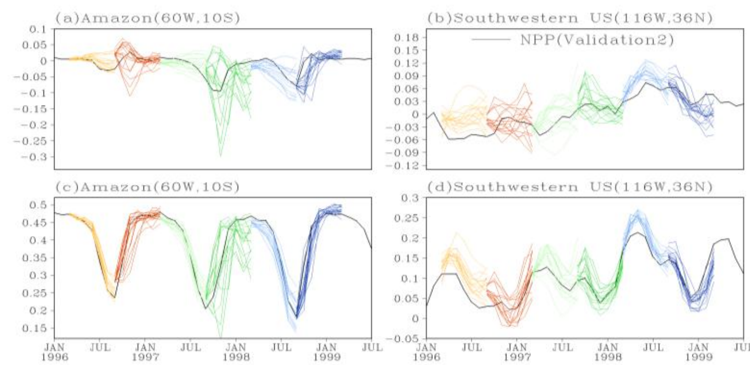

Figure 1. Example of of the CFS/VEGAS handcast: a time section of the predicted NPP anomalies kgC m^{-2} y^{-1} for two grid points, one over the Amazon, the other one southwestern US, compared to the validation (black line). Each line represents one individual member of a 15-member ensemble forecast. For clarity, the forecasts were 'thinned' to show only every 6 months and for a 6-month long forecast while the actual forecasts were monthly and 9 month long. The top two panels are for anomalies while the lower panels include seasonal cycle.

Operational forecast: set up and initial results

We have completed the initial setup of a one-way pseudo-operational forecast system. This is 'pseudo' in the sense that it was not actually issued, and the run was not always done in real time. However, it uses only the operational CFS input so it is what one would have got if it was done operationally. The system consists of: The following key steps are involved:

(1) A shell script was developed to automatically download CFS operational forecast once a day. These forecasts are archived only for 1 week, and the daily download is for safety.

(2) The data are processed by spatial interpolation. Climate variables such as precipitation and temperature anomalies are computed, then added to a climatology.
(3) An ensemble of 9 climate predictions drives the vegetation/carbon model.
(4) The forecast is conducted each month, with initial condition comes from the ensemble mean of the 1 month lead forecast from the previous month's forecast.

This system is being actively tested. A sample result (starts in May 2009) is shown in Fig. 2. It predicted a rise in land-atmosphere flux in association with 2009 El Nino. The predicted rise lags slightly behind the observations.

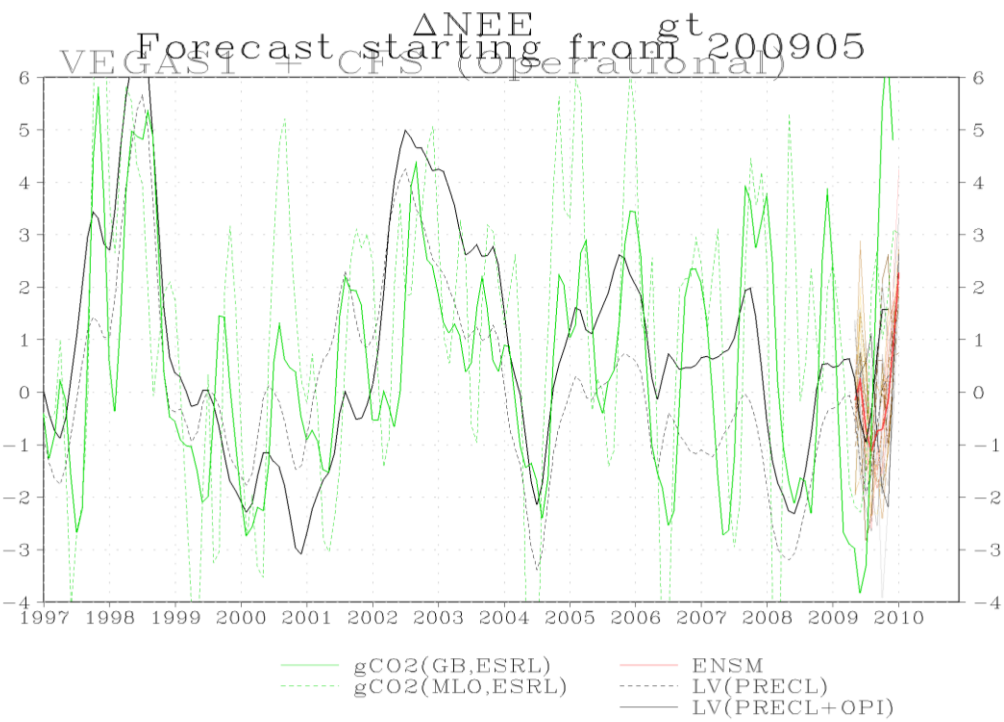

Figure 2. An example of experimental pseudo-operational forecast. The variable is net land-atmosphere carbon flux (NEE). The forecast started in May 2009. The ensemble forecasts are shown in thin redlines, with the thick redline indicates ensemble mean. The green lines are observed atmospheric CO2 growth rate (Mauna Loa and global mean from NOAA/ESRL). The black lines are 'validation' (NEE simulated by the carbon model, forced with observed climate; two precipitation datasets were used).

Simulating and understanding the seasonal and interannual variability in ecosystem productivity and carbon fluxes

Understanding of carbon exchange between terrestrial ecosystems and the atmosphere can be improved through direct observations and experiments, as well as through modeling activities. Terrestrial biosphere models (TBMs) have become an integral tool for extrapolating local observations and understanding to much larger terrestrial regions. Although models vary in their specific goals and approaches, their central role within carbon cycle science is to provide a better understanding of the mechanisms currently controlling carbon exchange. Recently, the North American Carbon Program (NACP) organized several interim-synthesis activities to evaluate and inter-compare models and observations at local to continental scales for the years 2000–2005. Here, we compare the results from the TBMs collected as part of the regional and continental interim-synthesis (RCIS) activities. The primary objective of this work is to synthesize and compare the 19 participating TBMs to assess current understanding of the terrestrial carbon cycle in North America. Thus, the RCIS focuses on model simulations available from analyses that have been completed by ongoing NACP projects and other recently published studies. The TBM flux estimates are compared and evaluated over different spatial ($1° \times 1°$ and spatially aggregated to different regions) and temporal (monthly and annually) scales. The range in model estimates of net ecosystem productivity (NEP) for North America is much narrower than estimates of productivity or respiration, with estimates of NEP varying between −0.7 and 2.2 PgC yr^{-1}, while gross primary productivity and heterotrophic respiration vary between 12.2 and 32.9 PgC yr^{-1} and 5.6 and 13.2 PgC yr^{-1}, respectively. The range in estimates from the models appears to be driven by a combination of factors, including the representation of photosynthesis, the source and of environmental driver data and the temporal variability of those data, as well as whether nutrient limitation is considered in soil carbon decomposition. The disagreement in current estimates of carbon flux across North America, including whether North America is a net biospheric carbon source or sink, highlights the need for further analysis through the use of model runs following a common simulation protocol, in order to isolate the influences of model formulation, structure, and assumptions on flux estimates.

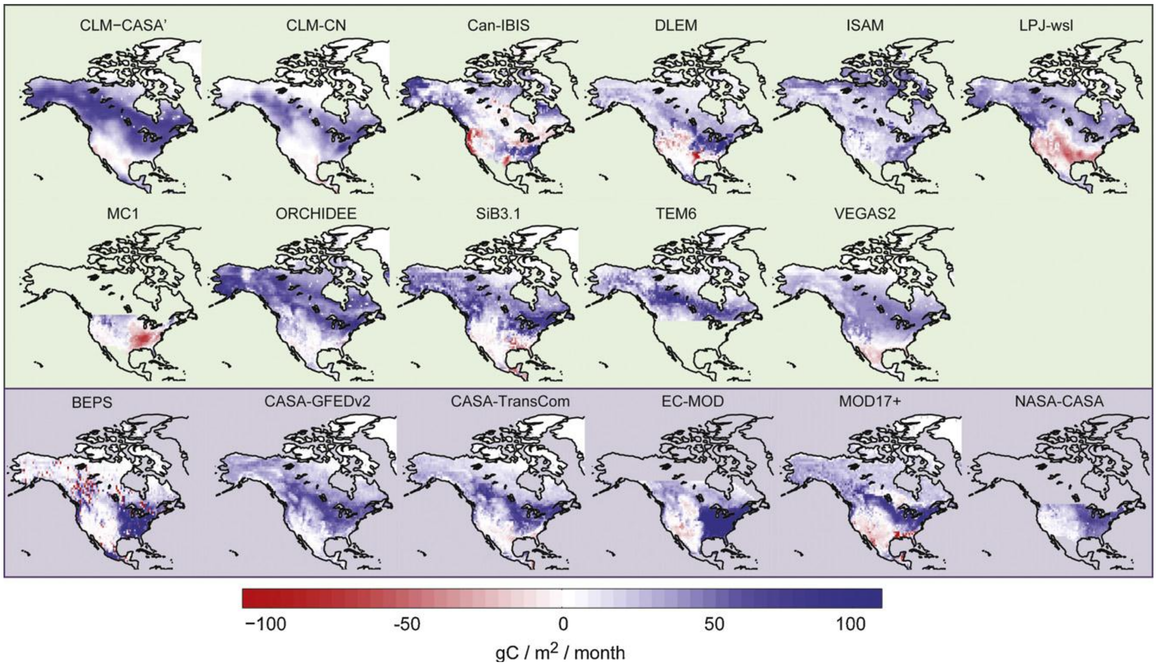

Figure 3: VEGAS model compared with a group of models used in the North American Carbon Program Interim Synthesis.